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Review Article

A brief review of the geographic ranges and ecological effects of three major invasive cyprinid species in Iran

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Abstract
The present study aimed to investigate the distribution status and ecological effects of the introduction of three major invasive fish species viz. *Hemiculter leucisculus*, *Carassius auratus* and *Pseudorasbora parva* in Iran. This review provides useful information about non-native species for readers. This research can play an important role to protecting aquatic ecosystems in Iran and other parts of the world.

Keywords: Biological invasion; distribution; exotic species; introduction; Iran

1 | INTRODUCTION

When a species finds a new habitat outside its natural range, it is considered an alien species. Alien species can become an invasive species in the newly occupied habitat under favourable conditions. Alien species may pose a threat to native biodiversity and become a significant driver of community change in the receipt habitat (Bonder *et al.* 2005; Findlay *et al.* 2015). Under such conditions, non-native species usually grow and reproduce very fast in the new habitats (Galib *et al.* 2021). Invasive species are usually highly adaptable to new conditions and are of superior competitive nature for food and space (Radkhah *et al.* 2016, 2018). These species may also transmit new diseases to native species, resulting in a significant reduction in the population of native species and even their extinction (Galib *et al.* 2021). In addition to the great damage that invasive alien species do to ecosystems, they can also cause significant economic damage (Radkhah *et al.* 2020a, 2021).

Cyprinidae is the largest family freshwater fishes with about 367 genera and about 3006 species (Nelson *et al.* 2016) distributed worldwide (Demurok and Ünlu 2001; Galib and Mohsin 2010). This family has about 42 genera in 123 species in Iran (Esmaeili *et al.* 2018). The members of this family (including common carp, silver carp and grass carp) are good source of nutrients with health benefits (Mohsin *et al.* 2012). There are many species in this family that have been introduced by humans and transport into an area outside of their native range (Sax 2001). Nowadays, the introduction of alien fishes is a mean to increase production of aquatic ecosystems (FAO 2005). In many countries, introduction of the exotic fishes also may be to improve the sport fishing, controlling of undesirable organisms and etc. (Kottelat and Whitten 1996; Jones *et al.* 2021). However, such introduction of non-native species has led native biota and the ecosystems under pressure. Therefore, the introduction of alien species across the world is of utmost importance to be studied. Hence, this study was conducted to investigate the distribution status and ecological effects of three well-known cyprinid invasive fishes viz. *Hemiculter leucisculus*, *Carassius auratus* and *Pseudorasbora parva* in Iran. This review can be useful for fisheries and environmental policymakers to manage and protect aquatic ecosystems. The data of the present study were collected from various sources such as papers, books, reports and websites.

2 | THREE NON-NATIVE CYPRINIDS

2.1 *Hemiculter leucisculus* (Basilewsky, 1855)

Common names: Common sawbelly, sharpbelly and Korean sharpbelly.
Local name in Iran: Tizeh-kuli (Esmaeili *et al.* 2018).

Synonyms:
Hemiculter eigenmanni (Jordan and Metz, 1913)
Chanodichthys leucisculus (Basilewsky, 1855)
Hemiculterella eigenmanni (Jordan & Mertz, 1913)
Hemiculter clupeoides (Nichols, 1925)
Hemiculter kneri (Warpachowski, 1888)
Squaliobarbus annamiticus (Tirant, 1883)
Parapelecus eigenmanni (Jordan & Metz, 1913)
Hemiculter schrencki (Warpachowski, 1888)
Cultriculus akoensis (Oshima, 1920)
Hemicultur clupeoides (Nichols, 1925)

Origin and native range: *Culter leucisculus* was originally described from rivers flowing into Bay of Tschili [Chihli], Beijing [Peking], China and is native to east Russia, rivers of China including Hong Kong and Taiwan, west Korea and Vietnam (CABI 2016). In Iran, *H. leucisculus* was first reported in the Anzali wetland (Holčík and Razavi 1992; Radkhah *et al.* 2020b).

IUCN Red List category: It is known as a least Concern (LC) species in IUCN Red List.

Habitat: *Hemiculter leucisculus* inhabits in large rivers with shallow water, pools, ponds, reservoirs, wetlands, marshes and lakes. This species swims near the water surface in stagnant waters and is highly tolerant to water pollution and low level of oxygen (Serov *et al.* 2006; CABI 2016). It species was reported in almost all inland waters of Iran (Radkhah *et al.* 2016).

Distribution: This species found in aquatic bodies of North Korea, South Korea, Hong Kong, Japan, China, Vietnam, Russian Far East, Uzbekistan, Afghanistan and Iran (Mustafayev *et al.* 2015). *Hemiculter leucisculus* has been reported in the southern Caspian Sea basin, including Sefid River, Anzali wetland and wetlands of Ala-Gol, Adji-Gol and Ala-Gol, Alma-Gol (Patimar *et al.* 2008; Mousavi-Sabet *et al.* 2013; Radkhah and Eagderi 2015) and the Hamun-e-Jazmourian basin (Radkhah *et al.* 2016); it is probably found in other Iranian inland waters (Esmaeili *et al.* 2018). Global distribution map of the *H. leucisculus* is shown in Figure 1.

2.2 *Carassius auratus* (Linnaeus, 1758)

Common names: Goldfish, crucian carp and karass.
Common names in Iran: Mahi-ye talaee, Kopur-cheh and Mahi-ye howz (Coad 2016).

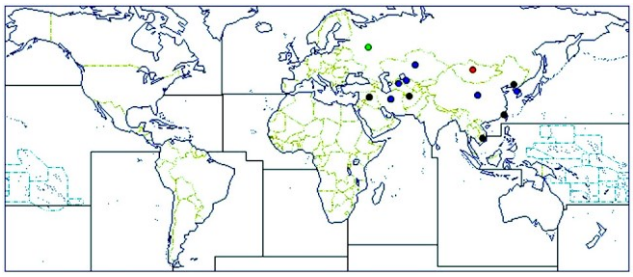

FIGURE 1 The distribution map of *Hemiculter leucisculus* (modified from CABI 2016).

Synonyms:
Carassius burgeri (Temminck & Schlegel, 1846)
Cyprinus gibelioides (Cantor, 1842)
Carassius encobia (Bonaparte, 1845)
Cyprinus nigrescens (Günther, 1868)
Cyprinus auratus (Linnaeus, 1758)
Cyprinus thoracatus (Valenciennes 1842)
Carassius pekinensis (Basilewsky, 1855)
Neocarassius ventricosus (Castelnau, 1872)
Carassius coeruleus (Basilewsky, 1855)
Cyprinus mauritianus (Bennett, 1832)

Origin and native range: Goldfish is native to Eastern Asia (areas in Russia, China and perhaps Korea and Japan) (Froese and Pauly 2016).

IUCN Red List category: This species classified as a Least Concern by the IUCN (Huckstorf and Freyhof 2016; Radkhah and Eagderi 2021).

Habitat: *Carassius auratus* inhabits a vast variety of aquatic bodies. This species lives in eutrophic systems, vegetated ponds and canals. It also is very tolerant of pollution and low oxygen concentrations in water (Özcan 2013).

Distribution: *Carassius* genus is widespread in Eurasian continent (Yerli *et al.* 2014). Goldfish is widespread in Australia, New Zealand, Europe, North and South America (Lelek 1987; Lorenzoni *et al.* 2010). This species is introduced to many aquatic ecosystems in Asian countries such as China, Japan, Malaysia, Singapore, Philippines, Uzbekistan, Bangladesh, Pakistan, Afghanistan and Iran (Kailola *et al.* 1993; Galib *et al.* 2013). In Iran, this species was reported in all inland water basins (Esmaeili *et al.* 2018; Radkhah and Eagderi 2020a). Figure 2 shows distribution map of *C. auratus* in world.

2.3 *Pseudorasbora parva* (Temminck & Schlegel, 1846)

Common names: Topmouth gudgeon, stone moroko (Britton and Brazier 2006) and false Razbora.
Common Names in Iran: Amurcheh.

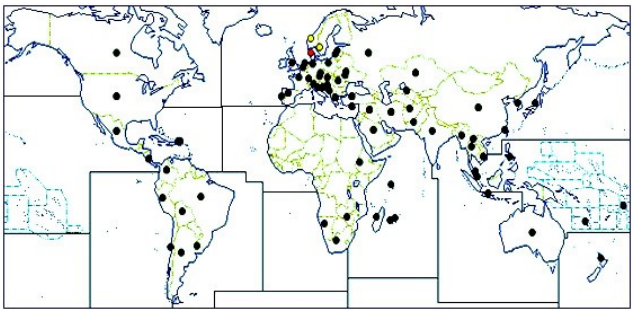

FIGURE 2 Global distribution map of *Carassius auratus* (modified from CABI 2016).

Synonyms:
Leuciscus pusillus (Temminck & Schlegel, 1846)
Fundulus virescens (Temminck & Schlegel, 1846)
Leuciscus parvus (Temminck & Schlegel, 1846)
Pseudorasbora monstrosa (Nichols, 1925)
Pseudorasbora altipinna (Nichols, 1925)
Micraspius mianowskii (Dybowski, 1896)
Pseudorasbora depressirostris (Nichols, 1925)
Pseudorasbora fowleri (Nichols, 1925)

Origin and native range: *Leuciscus parvus* Temminck and Schlegel, 1846 was originally described from Japan (Coad 2016). Topmouth gudgeon is native to Russia, Japan, China and republic of Korea (Banarescu 1999). This species is found in East Asia, including the Amur basin, Japanese islands and southern and western regions of Taiwan and Korean (Panov 2006; Gozlan *et al.* 2010a).

IUCN Red List category: According to the IUCN Red List, *P. parva* is classified as a Least Concern species (Huckstorf 2012).

Habitat: *Pseudorasbora parva* inhabits in rivers and lakes, but it also is found in eutrophic ponds and muddy pools with aquatic plants. Therefore, that *P. parva* has a wide tolerance of environmental conditions (Pinder 2005). Fureder and Pockl (2007) and Zahorska and Kovac (2009) stated that this fish is regarded as a pest in pond systems.

Introduction and distribution: *Pseudorasbora parva* was introduced into Europe with Chinese carps such as common carp, bighead, silver carp and grass carp (Caiola and De Sostoa 2002; Gozlan *et al.* 2010a, 2010b). This species is reported from the several European countries including France, Germany, Belgium, Denmark, Poland, Bulgaria, Italy, Czechoslovakia and England (Panov 2006). In addition, this species was introduced into other countries such as Armenia, Afghanistan, Taiwan, Uzbekistan, Azerbaijan, Turkey, Iran and etc. (Huckstorf 2012; Benzer 2020). Figure 3 shows the global distribution map of *P. parva*. In Iran, this species was first reported from the Caspian Sea basin and is now widely distributed across the country including Namak Lake, Hari River, Sistan, Maharlu, Urmia, Persis and Tigris River drainages and probably elsewhere (Esmaeili *et al.* 2018; Radkhah *et al.* 2018, 2020b; Ganjali *et al.* 2021).

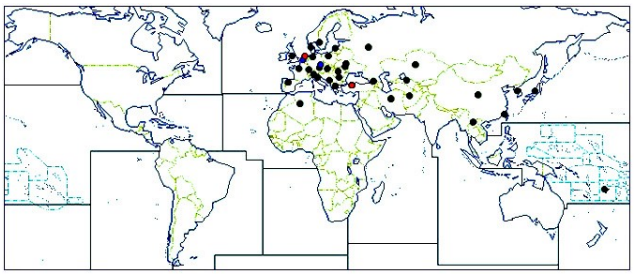

FIGURE 3 World distribution map of *Pseudorasbora parva* (modified from CABI 2016).

3 | ECOLOGICAL IMPACTS

The introduction of non-native species is a significant threat to biodiversity and ecosystems, causing extinction of native populations and loss of some ecosystem capabilities. The introduction and expansion of non-native species often entails huge costs, including agriculture and fisheries, and also affect some aspects of the human health (Davies 2015). In addition, introductions of non-native species are associated with high economic costs; e.g. in the United States, the cost of invasive species averaged about $137 billion a year (Simon 2012).

Some non-native fish species such as *Hypophthalmichthys nobilis*, *H. molitrix* and *Ctenopharyngodon idella* have been regularly added to inland waters by the Iranian Fisheries Organization and *H. leucisculus*, *C. auratus* and *P. parva* have been introduced along with such introduction activities (Esmaeili *et al.* 2014; Radkhah *et al.* 2016). Many other species have inadvertently been transferred to domestic ecosystems with the importation of Chinese carp (Esmaeili *et al.* 2014; Teimori *et al.* 2016).

Invasive species take on different mechanisms after being introduced to aquatic ecosystems. Some of them failed to expand and however, some of them did not even succeed in creating sustainable populations in the environment. In contrast, some invasive species, such as *P. parva*, spread rapidly and occupied important parts of aquatic habitats (Esmaeili *et al.* 2014). According to previous works (e.g. Esmaeili *et al.* 2014; Ganjali *et al.* 2021), populations of this fish that had moved to new areas grew rapidly and became dominant among fish communities. Thus, global concern about the environmental impact of *P. parva* has increased significantly.

Biological invasion is often associated with depletion of native species, which can alter biodiversity patterns and lead to biogenesis (Tran *et al.* 2015) i.e. species capacity for the formation of high-density populations can lead to the sharing of common food resources with native species and lead to overlap in ecological nests (Gavriloaie *et al.* 2014). In areas where *P. parva* has a stable population, it is able to strongly affect native ecosystems and it

is compatible with native carp in terms of nutritional sources leading indirect competition (Nowak and Szczerbik 2009). *Pseudorasbora parva* is a highly invasive species because it is able to tolerate adverse conditions. This species has a high environmental potential at low oxygen concentrations, organic pollution and even piscicide concentrations that are lethal to other fish species (Rosecchi *et al.* 2001; Radkhah *et al.* 2018). In addition, omnivorousness, short generation time, polyphilic spawning, early reproduction, high spawning, high reproductive effort, and parental care have increased the density and colonization of this non-native species in many aquatic ecosystems (Simon *et al.* 2011; Gavriloaie *et al.* 2014; Radkhah *et al.* 2018). Of course, other characteristics of this species such as small size, ability to spread quickly and adaptability to different environments also contribute to the success of its colonization (Pinder and Gozlan 2003). Gozlan *et al.* (2010a) stated that *P. parva* feeds on eggs and small fish native to the ecosystem. Therefore, the presence of this species in the inland basins of Iran and along with native species can be very dangerous. The negative effects of this species over time will be accompanied by a decrease in the density of native species.

Non-native species can host pathogens (Gozlan *et al.* 2005). Margaritov and Kiritsis (2011) identified a considerable list of different parasites such as Protozoa, Monogenea, Cestoda, Trematoda, Nematoda, Acanhocephala, Bivalvia, Crustacea and Hirudinea. Identified parasitic species include *Cryptobia branchialis*, *Ichthyobodo necator*, *Chilodonella hexasticha*, *C. piscicola*, *Lernaea elegans*, *Argulus japonicas* and *Trichodinella epizootica* in the skin and gills of invasive species in Bulgaria. Introducing these species with such a coexistence with different parasites can be dangerous for the health of other fish, especially natives. Different parasites have been reported in exotic fishes of Iran (Malek and Mobedi 2001; Barzegar and Jalali 2009; Pazooki and Masoumian 2012).

Another ecological impact of alien species could be their hybridization with native species. Hybridization can have a major impact on the genetic structure, conservation status of native fish populations and even their extinction (Rhymer and Simberloff 1996). Some of non-native species may interbreed with native species, potentially leading to changes in adaptation, resilience, and genetic diversity in local populations.

In conclusion, it can be said that a species introduced to a new habitat may establish, increase in number through successful reproduction, colonise and becomes invasive and pose a major challenge to the native biota and the habitat. Therefore, it is necessary to adopt management and conservation strategies to prevent the negative effects of these species on aquatic ecosystems.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHORS' CONTRIBUTION

Both authors equally contributed to the manuscript.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analysed in this study.

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